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# beaufort

November, 1981



DTVL

# beaufort

Vol. 1, No. 2 - November, 1981

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We would like your views and opinions on the content of Beaufort magazine. Simply drop us a line care of The Editor, Beaufort Magazine, Dome Petroleum Limited, .....

**The Editor**  
**Beaufort**  
**Box 200,**  
**Calgary, Alberta T2P 2H8**

## FREE SUBSCRIPTION

For those readers who would like to receive Beaufort on a regular basis, your name can be added to our mailing list by simply writing to Dome Petroleum Limited at:

**Circulation Manager,**  
**Beaufort**  
**Box 200,**  
**Calgary, Alberta T2P 2H8**



**Cover Photograph:** This dramatic photograph of the Tarsiut island caissons being positioned highlights the importance of engineering precision in the building of artificial islands in the Beaufort Sea. Working against limited time and the inevitable freeze-up which starts by October, Dome Petroleum Limited, the designers of Tarsiut, have a full winter's drilling season planned for this island which sits in 22 metres (72 feet) of water. Situated in the transition zone between shorefast and permanent pack ice, Tarsiut will experience the full range of ice conditions and has been extensively instrumented to learn the utmost about Arctic ice forces and thereby apply that information to future island designs. (Front and back covers photographed by Hans van der Wal).

Beaufort is published by Dome Petroleum Limited, Esso Resources Canada Limited and Gulf Canada Resources Inc. to provide the general public, and interested parties, background information on the long range development and production of hydrocarbon fuels from the Beaufort Sea and Mackenzie Delta. In terms of engineering and technical skills production is attainable in this region by the mid-80s. Before approval in principle is obtained from the federal government, a detailed report on the possible effects and impacts of such production must be prepared. This report, known as the Environmental Impact Statement, is to be completed in early 1982. The E.I.S. will address the issues and concerns raised by the production scenario. BEAUFORT will report on the progress of E.I.S. and the energy industry's evolving plans to address these concerns.

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**Calgary, Alberta**

# Esso and Gulf Join Beaufort Magazine

There are more than 40 oil companies with interests in the Beaufort Sea and Mackenzie Delta region, the three largest ones being Dome Petroleum Limited, Esso Resources Canada Limited, and Gulf Canada Resources Inc. Much of the impetus towards energy production in the Beaufort region has come from these companies, who have been among the pioneers in the search for oil and gas in the Canadian Arctic. These three companies are the major proponents of energy production in the Beaufort Sea and, as such, are directly involved in the Federal Environmental Assessment And Review Process (E.A.R.P.) which will help to establish environmental guidelines for future production.

With our second issue of **Beaufort Magazine**, Dome is pleased to announce that Esso and Gulf have joined us in the publishing of this and all future editions. For editorial functions Dome Petroleum will continue to be the contact for our readers. We encourage you to write to:

**The Editor  
Beaufort Magazine  
Box 200, Calgary, Alberta  
T2P 2H8**

A close liaison is maintained between the three companies on the ongoing Environmental Assessment and Review Process, and our readers are welcome to contact Esso or Gulf on subjects of specific interest to their operations and future plans. The addresses are:

**Esso Resources Canada Limited  
237 - 4th Avenue S.W.  
Calgary, Alberta**

**Gulf Canada Resources Inc.  
401 - 9th Avenue S.W.  
Calgary, Alberta**

## FEARO Update

The dates and locations for the first series of public meetings on the Beaufort Sea Environmental Assessment Guidelines have been finalized. By the time our readers receive their issue of **Beaufort Magazine** many of the meetings will have taken place. The purpose of the meetings is to discuss the draft Environmental Impact Statement (EIS) Guidelines, the first draft of which was released in June of this year.



*Opening session of the Federal Environmental Assessment guideline hearings, in Aklavik, N.W.T., on November 4th.*

There will be both Community and General Sessions held between November 4th and December 4th, with the former limited to representatives and members of potentially affected communities in the North. Members of the general public, and other special interest groups are welcome to attend the General Sessions. Any participants at the meetings may make a submission in writing, although the Panel

Secretariat in Vancouver, B.C. had a cut-off date for written submissions of October 23rd. This was to ensure that a bound compendium of the opinions expressed would be available prior to the start of public meetings on November 4th.

The first meeting, a Community Session, opened in Aklavik, N.W.T. on the 4th, followed by similar sessions at Sachs Harbour (Nov. 5th), Fort Norman (Nov. 17th), Tuktoyaktuk (Nov. 18th), Inuvik (Nov. 19th). The first General

Session was the following day, the 20th, in Inuvik. Subsequent general sessions take place in Whitehorse, Y.T. on the 23rd, in Yellowknife, N.W.T. on the 25th, Calgary, Alberta on the 26th and 27th, in Pond Inlet, N.W.T. on December 1st, and finally in Pangnirtung on the 4th. A community session will be held in those latter two communities on November 30th (Pond  
*Continued on following page*

Inlet) and December 3rd (Pangnirtung).

Our readers are reminded that the government Beaufort Sea Funding Review Committee recently announced that there are funds allocated to assist public participation in the formation of EIS Guidelines. Questions concerning these funds, or the program itself can be directed to:

**Mr. P.J. Paradine,  
Federal Environmental  
Assessment Review Office  
Hull, Quebec K1A 0H3  
Telephone (819) 997-1000**

Details on the meetings will be publicized in northern newspapers and radio stations, as to times and locations. The procedures to be followed at the meetings and specific subject matter covered at certain of the communities can be obtained by phoning Mr. David

Marshall, Executive Secretary of the Beaufort Sea Environmental Assessment Panel, in Vancouver (604) 666-2431.

### **Letters & Requests From Our Readers**

The response to our premier issue of **Beaufort Magazine** has been very encouraging from all quarters, and we have received a steady stream of mail from many parts of Canada and several foreign countries asking to be added to our complimentary mailing list. Requests have come from private individuals, corporations, consulting firms, as well as government and university departments. A large number of public and institutional libraries have requested copies for their files, which is gratifying because we view **Beaufort Magazine** as an educational vehicle, to inform the general public and all interested par-

ties about the issues and concerns surrounding Beaufort development and the Environmental Assessment And Review Process.

**Beaufort Magazine** was created, as pointed out in our first issue, to provide timely and informative information on the oil industry's activities in the Beaufort Sea and Mackenzie Delta region of Canada. It is aimed at the general public and the non-technical reader. Future issues of the magazine will tell you about the challenges in oil exploration and production, as well as the concerns surrounding this most vital of pursuits. Our readers are encouraged to write in and express their opinions on our stories, and the ongoing Environmental Assessment and Review Process. The magazine is viewed not only as educational in content, but as a forum for opinion from all sectors of Canadian society. We look forward to hearing from you.

## **Notice To The Northern Communities**

### **TRANSLATION**

The premier edition of **BEAUFORT Magazine** printed in August has been translated into Inuktitut and the language of the western Arctic and can be obtained by writing to:

**The Editor  
Beaufort  
Box 200,  
Calgary, Alberta T2P 2H8**

Translated versions of subsequent editions of the magazine will be available from the above address approximately one month after the publication of the English language edition.



## THE MIGHTY MACKENZIE RIVER

The drainage basin of the Mackenzie River is one of the largest in North America covering an area of 1,900,000 square kilometres (730,000 square miles). The headwaters reach back into parts of British Columbia, Saskatchewan, Alberta and the Northwest Territories and are collected by a large system of rivers flowing into Great Slave Lake. From here the Mackenzie River flows in a north-westerly direction for about 1,600 kilometres (1,000 miles) before discharging through the Mackenzie Delta into the Beaufort Sea. Its major tributaries are the Great Bear, Liard, Nahanni, Keele, Arctic Red and Peel Rivers. The Delta is an enormous maze of channels interwoven with each other, flooded or dry, frozen or open, dependent upon the time of year. The Delta begins just north of the village of

Arctic Red River. South of Richards Island the main channel separates into numerous smaller waterways, the largest of which are East Channel flowing into Kugmallit Bay, and Reindeer Channel which flows westward into Shallow Bay.

Apart from the Amazon River in South America and the Mississippi-Missouri system of the United States, the Mackenzie is the largest river in the Western Hemisphere. By comparison with another well known Canadian river, the Fraser River in B.C., the Mackenzie has a peak flow four times greater and drains a geographic area nine times larger!

The Mackenzie River has been a lifeline for the people of the western Arctic for many generations. Alexander Mackenzie, the explorer for whom the river is named, was far more interested in furs and a

route to the "Great Western Sea" when he paddled down it in 1789, than in finding oil or establishing transportation routes to the Arctic. But in common with many other river deltas around the world, there are numerous potential oil and gas bearing structures in the Mackenzie Delta-Beaufort Sea region, the result of millions of years of sediment accumulation and geological change. The first concrete evidence of this Arctic oil was a well drilled at Norman Wells which found oil in 1919. That well was not far from where Alexander Mackenzie reported finding "...petroleum like pieces of yellow wax...". It was the forerunner of a 500 million barrel oil field.

The importance of the Mackenzie River as a transportation route has increased with oil industry activities over the past two decades, and

even today it is the most important and least costly way for transporting cargo. For four months of the year shallow draft barge trains pushed by tugs depart Hay River and Fort Simpson in the south, delivering cargo to communities and industrial centres all the way north to the Beaufort Sea coastline. Such a barge train can deliver up to 5,000 tons of cargo on the trip north. An average round-trip from Hay River, on the southwest shore of Great Slave Lake, to Tuktoyaktuk takes three weeks.

The Mackenzie River transport system is presently able to handle between 500,000 and 600,000 tons per year. In 1979 the River transported 260,000 tons of freight, about half of which was fuel. Other

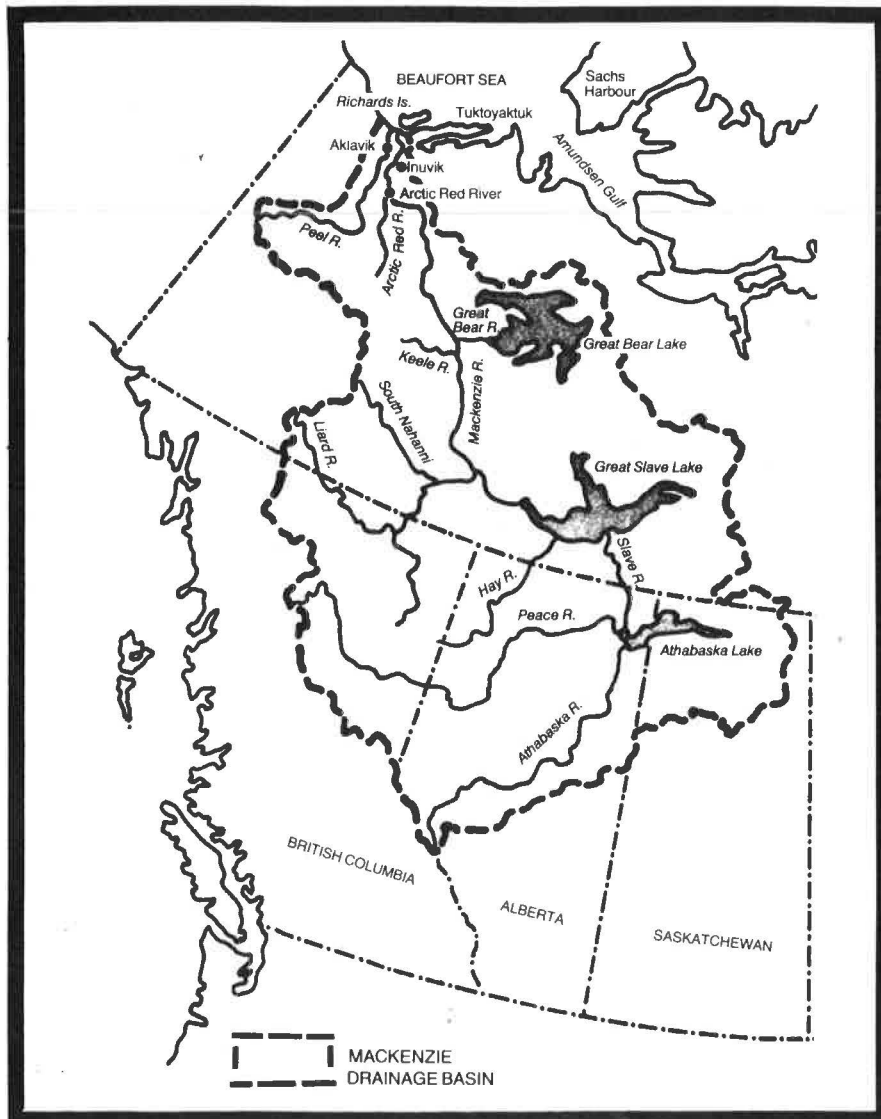
main cargoes included drilling consumables, barite, potash, as well as general supplies for the many northern communities. Even in the winter months the Mackenzie River serves as a transportation route - a road is ploughed right on the ice of the river, extending the Dempster Highway over the ice from Inuvik to Tuktoyaktuk and Aklavik. That ice road is critical to the oil industry's operations because it permits the transport of supplies by truck all winter long. During the winter of 1980 around 500 truckloads of goods were moved up the Dempster via Inuvik to Tuktoyaktuk, including Dome Petroleum's complete new 350 man camp constructed last winter. The Ya Ya Lakes gravel quarry located on Richards Island

provides building materials for the industry, and that gravel is likewise transported in trucks over the Mackenzie ice highway.

One can gain a better idea of the size and flow of the Mackenzie River by looking at some of the measured statistics. The average annual flow is more than 8,500 cubic metres per second (over 300,000 cubic feet per second) with peak loads being three times higher than that. Average daily suspended sediments deposited by the river into the Delta region during the maximum flow period from June to September exceeds one million tons a day. Peak loads of more than 20 million tons a day have been recorded. Such enormous volumes of sediment contain within them most of the chemical elements known to man, and in quantities which are quite significant. For example, the Mackenzie deposits on the floor of the river delta and Beaufort Sea an estimated 24,000 kilograms of mercury a year, or about 66 kilograms a day. Other metals such as copper run into the 50 million kilogram level annually, with lead estimated at a minimum of 3,800,000 kilograms for the four summer months alone, and zinc about 170 million kilograms annually.

Concern has been expressed about the disposal of drilling wastes, particularly drilling mud, in the Beaufort Sea and its possible adverse impact on the biological food chain. Drilling muds contain mainly clay, barite, salts and water; the barite being a heavy inert mineral mined in various places such as Nevada, Nova Scotia and soon the Yukon. However, the barite generally contains minor concentrations of impurities such as heavy metals in a chemical form similar to that brought down by the river.

Relative to the previously cited figures for Mackenzie River deposition of metals, a typical drilling well might deposit .055 kilograms of mercury a day into the sea, 10 kilograms of lead daily, 18 of zinc, and 1.5 of copper. Industry and government have carried out several major research programs to evaluate the impact of drill muds



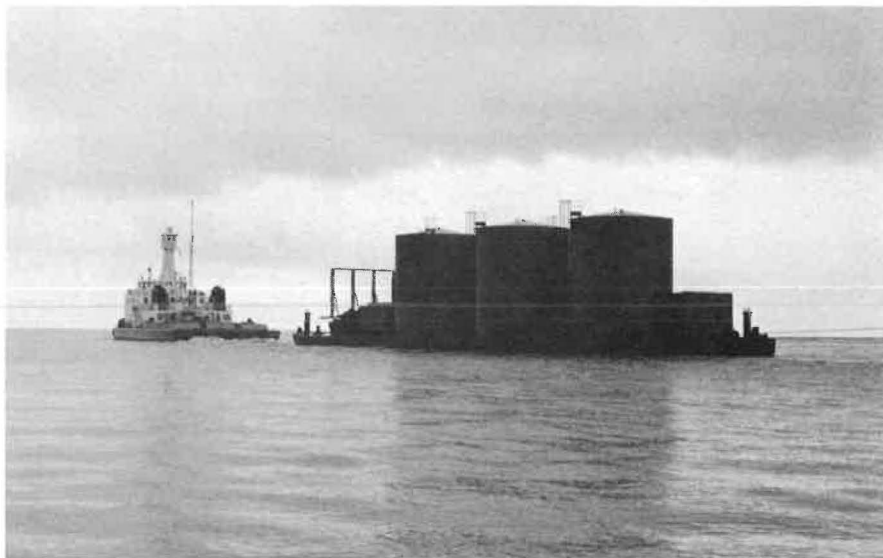
disposal into the area. Based on this research, and from experiences elsewhere, it appears that the drill muds themselves cause, at most, limited, local, short-term impacts mainly to the sea floor life. In addition the large quantity of sediment brought into the sea by the Mackenzie appears to help in gradually burying both the natural sediments and drilling mud deposits in most locations. This not only causes a dilution of the drilling wastes but tends to isolate them from the water and eventually the biosphere.

It is this never ending process of deposition which takes place in the Delta that encouraged geologists to think about the potential of the region as an oil producer. Petroleum originates from the remains of living organisms, particularly plankton and marine plants and animals, which were entombed at the bottom of the ocean by thick layers of sediment deposited by rivers such as the Mackenzie. Over millions of years the bottom layers of sand compressed into layers of porous sandstones, dense shales, and limestones. The oil and gas moved because of the relentless pressure and weight of earth and rock above it, and upheavals in the earth's crust below. Over millenia the oil seeped upwards into the porous sandstone levels, which functioned like sponges to absorb it. Dense shales and limestones lying above acted as lids on this upward seepage forming traps for the oil and gas. It is these pockets or traps of oil which are sought after around the world. Some of the most extensive oil traps have been found in regions which were once the floor of some ancient sea, the most obvious one being the Saudi Arabian desert. But the shallow areas of existing water bodies such as the Gulf of Mexico and the Beaufort Sea are equally promising.

Scientists have known for some time that most of the Beaufort Sea floor has a several metre thick surface layer of clay. However, recent studies by the oil industry, in cooperation with the government, to find new sources of dredged material revealed that if one digs

down below the clay in the right places, large deposits of sand can be found which are very useful as fill for island building. For many potential offshore island building sites this will greatly reduce the sea hauling distance involved to borrow sites, saving both time and money during the construction phase. The surveys done by the oil industry in the last year, particularly along ancient river channels which are now buried below the seafloor, brought to light not only sand but also gravel which can be 'harvested' for building. These deposits, the result of millions of years of Mackenzie River outflow can be found well out into the

shallower and warmer waters as they migrate from their winter home in the Bering Sea. Concern has been expressed that year to year variations in beluga whale numbers, especially reductions in the Delta area, was evidence that oil industry activities were frightening them away. Nine years of ongoing research are showing that the natural break-up pattern of the shore-fast ice has by far the greatest influence on the yearly distribution of whales in the estuary. If the shore-fast ice does not break-up by the end of June or early July, belugas may be blocked from entering certain areas of the estuary. This occurred in



*The majority of cargo on the Mackenzie River, including these oil storage tanks, are towed north by barge. (Photo courtesy NTCL Limited).*

Beaufort - up to 100 kilometres (60 miles) offshore in 50 to 70 metres (130 to 195 feet) of water.

The Mackenzie River Delta is a natural gathering place for biological life; fish, birds, moose, caribou, and offshore, polar bears, seals, and whales. The Delta has been described as a giant sponge from which wildlife draws nourishment and within which it is protected. The beluga whale, for example, seeks out the warmer waters of the Mackenzie Delta and its estuaries to give birth to its calves. Because the ice of the Delta breaks up earlier in the spring than does the shore-fast ice of the Beaufort, the whales are attracted to these

1980 at Kugmallit Bay. In 1981 however, shore-fast ice breakup in front of the Delta proceeded quickly, allowing large numbers of whales to enter the same bay.

The most impressive thing about the Mackenzie River, the Delta and the Beaufort Sea into which it flows, is that it appears to support man's activities equally with those of wildlife, and seems to do it effortlessly - almost as though it was conscious of its great age, and that the river will be there long after mankind has passed away. In geological terms, man's search for oil there is but a flash, a mere 'hiccup' compared to the timeless flow that is the Mackenzie River.

# The Building of Tarsiut ;

## The Beaufort's First Caisson Retained Island

Photos by Hans van der Wal

*The four independent concrete caissons of Tarsiut, viewed from the air, form a hollow square which is filled with sand and gravel fill. Each hollow caisson weighs 5,300 tons and is connected at the corners by steel doors to contain the fill.*

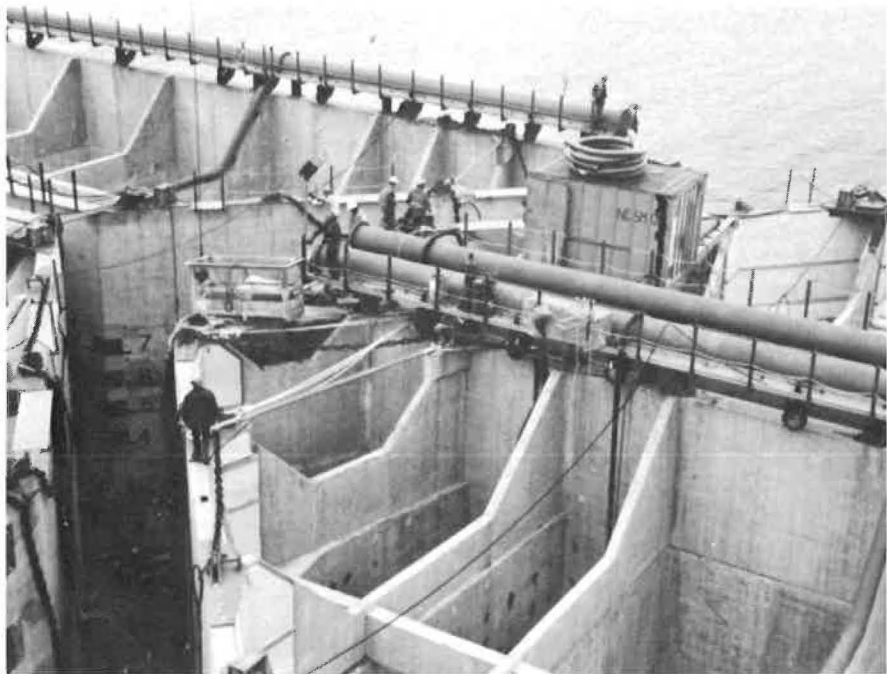


The 19 islands built to date in the Beaufort Sea have had gently sloped beaches often in combination with sandbags and filter cloth to form their defensive perimeter against the elements. The so-called sacrificial beach island is characterized by long, gradual beaches around the drilling surface, against which waves can break, dissipating their energy. In the winter ice sheets bend against the beach and ride up onto it, forming a protective rubble field. To provide additional wave protection sandbags have been used, laid over filter cloth. Sacrificial beach islands can be built readily in shallow water less than 20 metres (65 feet) at locations close to borrow material (i.e. near sites of sand and gravel fill). However, to use the same techniques in deeper waters is considered impractical because of the huge quantity of dredged material required. Moreover when island sites are located a long way from borrow areas, a more efficient use of dredged fill is needed. Therefore a different solution has been developed using retained caissons and steeper dredged slopes.

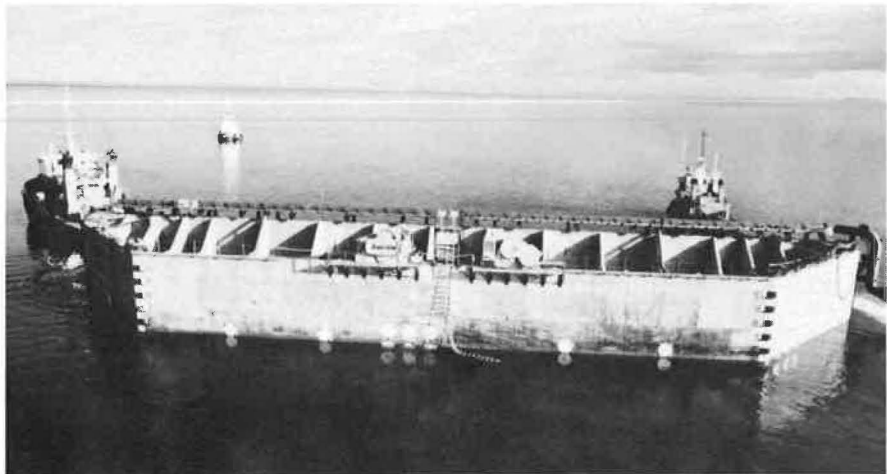
The first application of this new type of island is Tarsiut, built during the summer and fall of 1981. Located about 40 kilometres (25 miles) northwest of Richards Island, Tarsiut sits on the borderline between the landfast ice zone and the seasonal pack ice in 22 metres (72 feet) of water. Unlike Issungnak, a sacrificial beach island sitting in 19 metres (62 feet) of water, Tarsiut required much less sand and gravel fill to create the underwater hill, called a berm, that is its foundation.

Less than half the volume of dredged material used for Issungnak

*A better appreciation of scale is gained by comparing the size of the construction workers standing on the top of the caisson with the ribbed compartments (photo 2) or the size of the tugboats towing the floating boxes (photos 3 and 4). The metal piping running along the top of the structure was used to pump in the water and fill, after the caissons were placed in position at Tarsiut.*

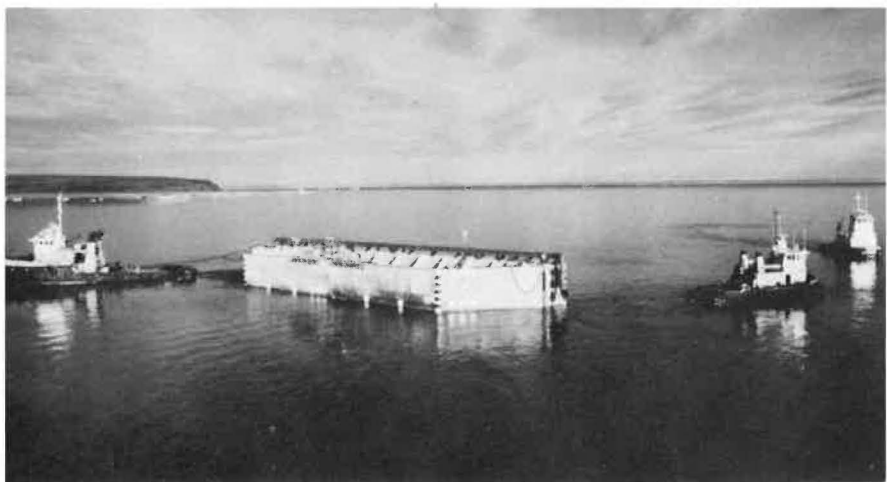


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was needed. This is for two reasons - firstly, Tarsiut was built with a more steeply sloped berm foundation with a 1 in 5 slope, compared to a 1 in 15 slope for Issungnak. Secondly, the berm does not break through the water surface but rather ends about six metres (20 feet) below the waterline.

To penetrate the waterline at Tarsiut a new technique was used. Four floatable (light weight), high strength, concrete boxes called caissons were set down on the top of the sand berm. Each caisson, if viewed from above, would look like a 'shoebox' with angled ends, measuring 11 metres (36 feet) high, 15 metres (49 feet) deep and 80 metres (262 feet) long. The four caissons are independent of each other and weigh 5300 tons apiece. After placement on top of the sand berm a joint closure system is used at the corners, using steel doors to contain fill material. The inside of the caissons have a hollow, ribbed structure with multiple compartments. The walls and ribs of the caissons are reinforced with steel posts and tensioning cables; the hollow compartments were subsequently filled with sand at the Tarsiut site.

The caissons cost approximately \$27 million dollars to construct in Vancouver, B.C. and were transported by sea to the Beaufort location during July of 1981. The caissons were loaded onto a submersible barge in the following way. First, the barge was loaded up with water ballast until all but its control tower was below water. Then the caissons which float because they are mainly hollow were maneuvered over the top of the barge. After this the water ballast was pumped out of the barge and it was raised along with the four caissons on its deck. The unloading procedure, which took place in Pauline Cove at Herschel Island, was simply a reversal of the loading method.

Prior to placing the caissons in position the underwater berm had been built up to within six metres (20 feet) of the sea surface using

dredged material. Laying that foundation was started by pumping sand through a downspout that was gradually moved around the outer ring of the island base. This created a donut shaped mound called a bund. The centre of this bund was then filled with sand, followed by the laying of another bund. This was repeated until the berm, or hill, had been built up to the desired height and slope. Stopping the berm short of the surface makes it less subject to wave erosion.

After unloading, the floating caissons were towed by tugs to the Tarsiut site where they were placed over the leveled underwater berm, anchored into position and sunk down by flooding the compartments. Resting upon the berm foundation, the caissons rise five metres (16½ feet) above the waterline. After placement the water ballast was displaced with sand fill, providing a very sturdy perimeter for the island. After solving some initial difficulties with some of the doors joining the caissons' corners, the interior of the island, looking like a hollow square if viewed from above, was filled in with sand right up to the top of the walls.

More sand and gravel was placed until the top surface was built up to 7½ metres (24½ feet) above the waterline. To provide protection from wave splash, sandbags were placed around the upper island perimeter. Below the sea around the bottom of the caissons a protective layer of gravel and rock was placed to further protect the island against wave and ice erosion. By the end of October, even while gray ice (15 cm. thick) was forming, the drilling hardware, accommodation quarters, and all the necessary consumables were being loaded onto the island using large cranes, in preparation for the upcoming drilling program. Naturally industry is very interested in the success of Tarsiut as a drilling island, but it is more than that - the design concept is a forerunner to future production islands.

As the prototype for what will be a new generation of islands, Tarsiut has been equipped with more than a

million dollars worth of instrumentation, turning it into a research laboratory on the Arctic's physical forces. Islands with shallow beaches are difficult to instrument and ice grounds out on the beach before ever reaching the main island. Like the Hans Island research program, Tarsiut will reveal much to the industry about ice forces.

These ice forces are being measured in several ways. Inside each caisson are 14 diaphragms, separating the compartments, which transfer the ice pressures on the front walls to the back walls. All of the diaphragms in the north and east caissons have strain gauges at four different levels inside them to measure the strain upon the diaphragm. The information from these gauges can be used to calculate the ice forces on the whole structure.

In addition there are three mechanical systems attached to the outside of the caissons. On the east wall there are four 4m<sup>2</sup> plates supported by oil-filled flat jacks - essentially they are envelopes of steel containing oil; when squeezed the oil pressure increases, thereby measuring the pressure exerted on the outer wall. On the north face are mounted many circular plates which measure 88 cm. (34½ inches) in diameter - 12 of these plates contain shear bars which deform and indicate load via strain gauges, while the other 11 plates have an oil filled coil under pressure.

All the data obtained from these ice force measuring systems will be entered on a 700 channel data acquisition system and then recorded on magnetic tape under computer and operator control. The data will allow researchers to relate measured forces to the prevailing ice conditions. This is not the only instrumentation on the island. There are 44 soil instrumentation cells in the caissons to measure the pressure of the soil against the concrete. There are also piezo-electric sensors which can measure the "pore pressure" inside the soil itself. Slope indicator devices will monitor fill movement, and the distance between adjacent caissons will also

be monitored. A major field program will be mounted several times during the winter where scientists will go out onto the ice around Tarsiut to measure its thickness, profile, strength, temperature, and so on - information which is important to accurately interpret the ice force information.

It can be seen from the preceding narrative that Tarsiut represents a major step forward by the oil industry and that every effort is being made to accumulate essential data needed for the next generation of development or production islands. The exact design of islands like Tarsiut can vary in the future and, in

fact, there are other shapes and styles of caisson which may be employed in the Beaufort, because it is important to find the optimum shape which will resist both ice and waves, and yet be practical to build. If the Tarsiut island is abandoned the caissons can be re-used at another site by removing the sand fill, refloating them, and towing them off to another island site.

Now that the Beaufort is freezing over, the first thin ice floes are already breaking harmlessly against Tarsiut's caisson walls. As the ice thickens it will ground out on the island's berm out to a water depth of about 20 metres (65½ feet),

forming a rubble field with piles of ice up to 15 metres (49 feet) high. During winter this rubble field will provide a natural shield against further ice impacts, so that even if the thickest pack-ice arrives at the island it will be diverted away. Judging by the fact that the polar pack-ice remained far north of the drill sites through the 1981 freeze-up period, it is unlikely that Tarsiut will be impacted by pack-ice in its first winter of drilling. But whatever the ice conditions, Tarsiut will be capable of handling them and, while doing so, will be generating a wealth of scientific data for the production islands of the future.

*Caisson structures used at Tarsiut are only one of several possible engineering solutions, and the shape and size of the caissons can be varied to meet specific requirements.*





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# TUKTOYAKTUK

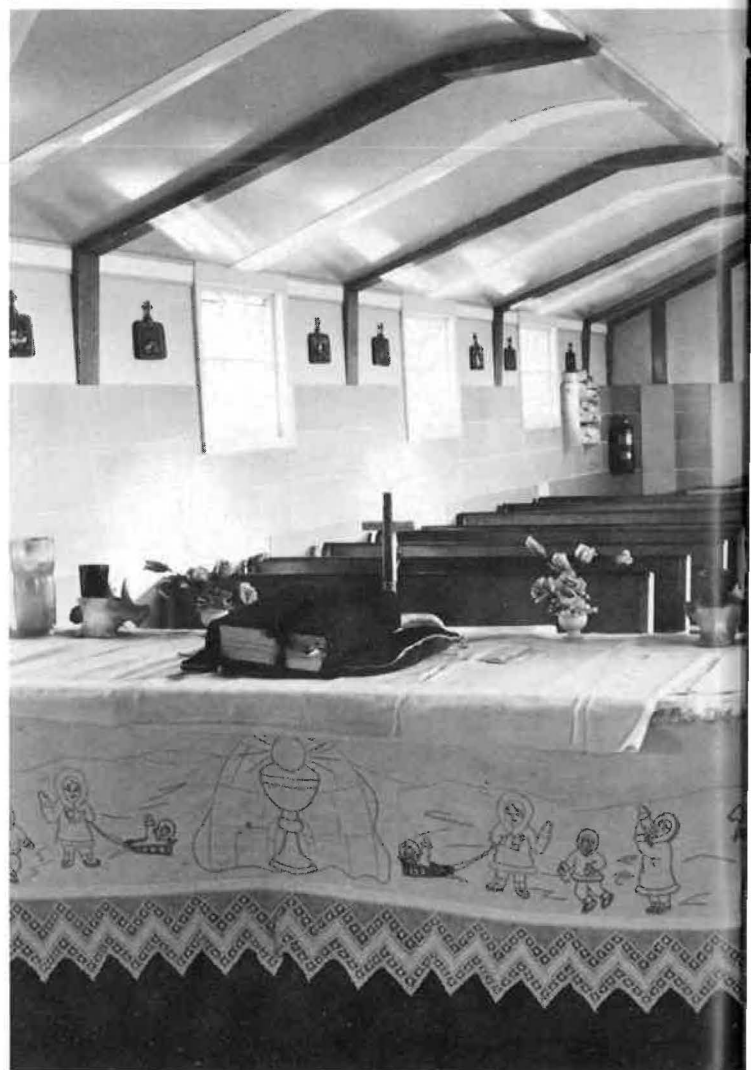
By Harry Palmer

Tuktoyaktuk began during the 1930s when the closing of posts at Herschel and Baillie. The village has been closely tied to industrial development, the Early Warning (DEW) radar line, and exploration. It has good, natural harbours along the Arctic coast and is a transportation centre. The Tuktoyaktuk has a wharf which can handle jet transport aircraft.

The population of Tuktoyaktuk is 760, and the remaining 10 percent being non-Eskimo. Most are not original Mackenzie Eskimos, but were introduced by the white man in the 19th century.

Our photographer is Harry Palmer, who has spent a few days capturing the people of the region for BEAUFORT magazine. In future editions of the Beaufort/Mackenzie region.

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# K PICTORIAL

y Palmer

n a fur trading post was built there after the  
lands. With the decline of fur trading, the  
projects such as the building of the Distant  
ation for oil and gas. It has one of the few  
inland and this has encouraged its use as a  
port now has a 6,000 foot gravel runway

out 90 percent of whom are Inuit or Indian,  
ative. The majority of the inhabitants were  
and particularly on Baillie Island, although  
he latter died away because of diseases in-  
y, during the whale hunting era.

works have been nationally exhibited, and  
architecture and landscape of Tuktoyaktuk  
we will feature other Arctic communities of



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1. Father LeMeur, the Roman Catholic priest for the village of Tuktoyaktuk.

2. The church altar which uses reindeer antlers and seal skin for some of its decorations.

3. A view from the church altar, with the native altar cloth, edged in seal skin.

4. One of the oldest residents of Tuktoyaktuk is Koiksak Raddi, aged 79.

5. Jimmy Jacobson, a long time resident of Tuktoyaktuk, with his grandson, Gilbert.



*Bessie Andreson in the fur shop.*



*Annie Emaghok, (left), and Cora Kimiksana work on the design of fur garments in the Tuktoyaktuk fur shop.*

*The village of Tuktoyaktuk, with boats in foreground.*



# Whale Life in the Beaufort Sea

The Beaufort Sea is the home for many species of marine life, the largest being whales which migrate into the region during the summer months. Whales are warm blooded, air breathing mammals belonging to a biological order known as Cetaceans - an order which includes all types of whales, dolphins, and porpoises. Based upon their methods of eating, cetaceans are divided into two sub-orders - toothed whales (odontocetes) and baleen whales (mysticetes). The Beaufort Sea is a summer feeding home for two main species, a toothed whale called the beluga or white whale, and a baleen whale called the bowhead.

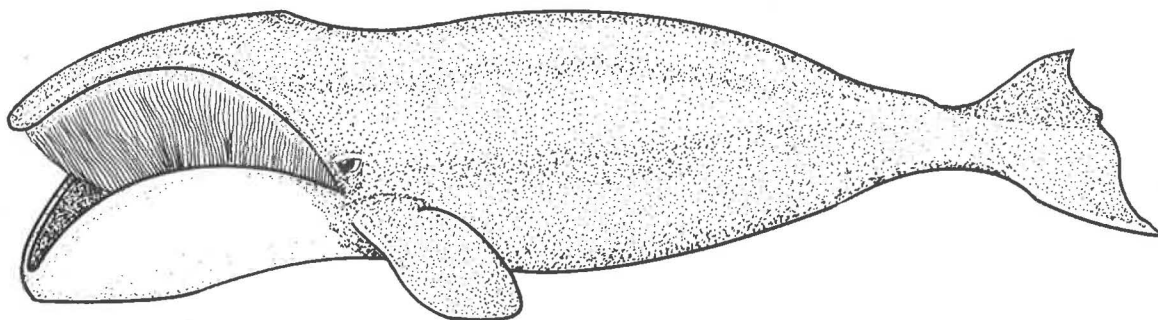
Most of the smaller species of whales, including the beluga, have peg-like teeth which are useful in catching fish. The baleen whales, on the other hand, which include the bowhead and even larger species reaching lengths of 100 feet, have mouths equipped with rows of horn-like plates which have coarse, bristled edges. These plates, called

baleen, hang from the whale's upper jaw and act as a sieve to filter large quantities of plankton, the whale's main food source. Baleen whales do not have teeth and to accommodate the enormous volume of baleen their jaws are very large. The head of a bowhead constitutes about one third of its total body length. When eating, it swims through the sea with its mouth open, taking in tons of seawater containing plankton. When the mouth is closed, the tongue is pressed against the back of the baleen plates, thereby squeezing out the water, leaving behind the food.

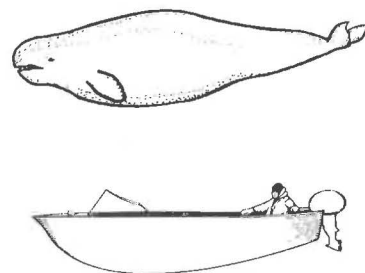
Our knowledge of whales is often sketchy and many details of their breeding and feeding habits are unknown. It is only in recent years, for example, that any scientific observation has been undertaken on belugas and bowheads in Arctic waters. Much of our knowledge is derived from two centuries of seafaring stories and folklore passed down from the period when whale hunting was a major industry in

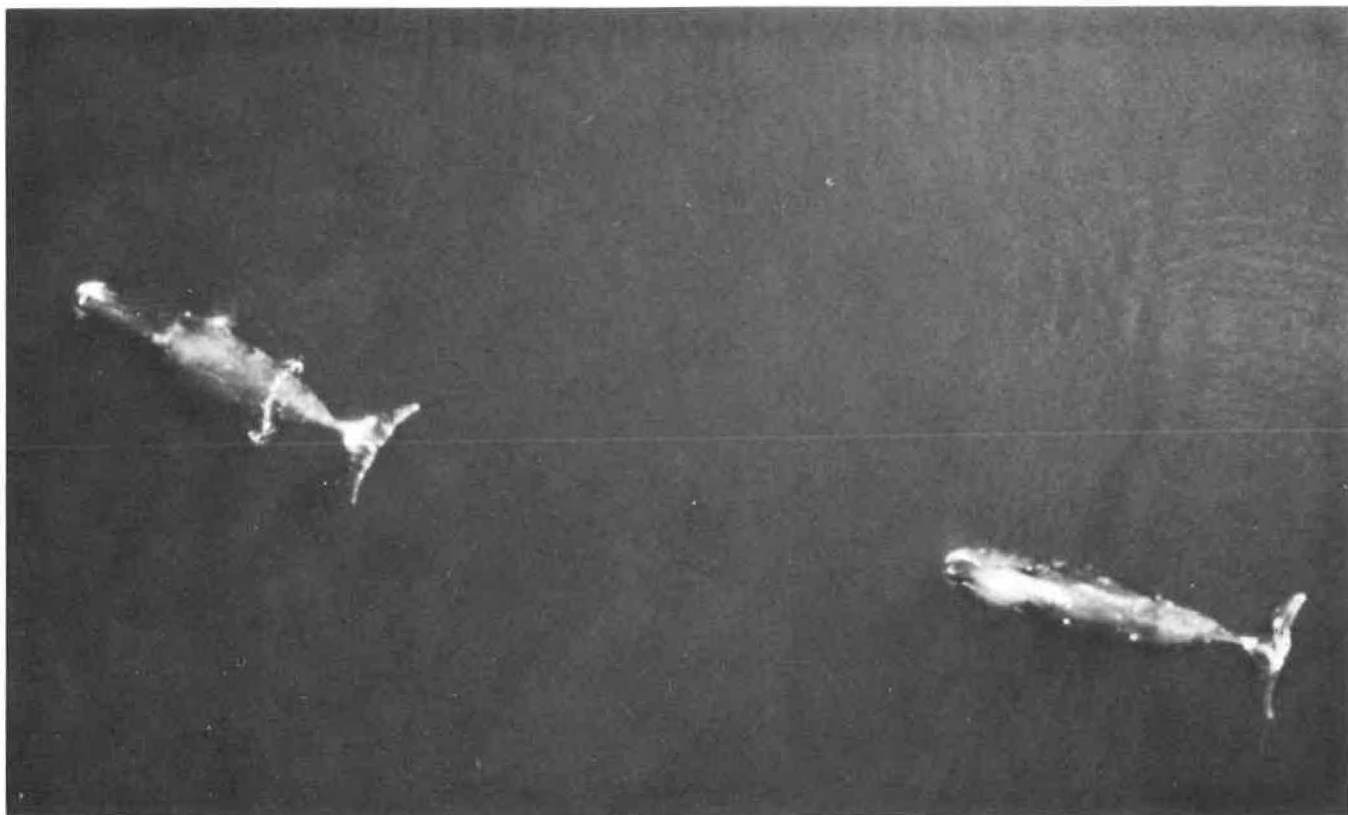
Europe and North America. Belugas are far more plentiful than bowheads and have been studied in captivity in aquariums. A beluga can be as long as 18 feet, but a bowhead can grow to a length of 60 feet and a weight of more than 60 tons. Because the bowhead has large amounts of blubber and baleen, it was a major target of whalers in the 19th and early 20th century. Its carcass could provide up to 80 barrels of oil for lubricants, lamps, and commercial products, and 1,500 pounds of baleen could be turned into corset stays, fishing rods, broom handles, and many other utility items. From an estimated population of more than 18,000 in the mid-19th century, the bowhead today is an endangered species, with an estimate of approximately 2,300 occurring in the Beaufort Sea region.

The beluga or white whale is estimated to number some 30,000 in North American waters, with as many as 7,000 having been observed in the Mackenzie River estuary



*These scale drawings portray the two common whales in the Beaufort Sea, the 18 foot beluga and the 60 foot bowhead. A man in the outboard motor boat gives a dramatic size comparison between it and the bowhead. The head of a baleen whale is very large, and can strain tons of plankton through its sieve-like mouth in a single meal. The beluga is a toothed whale and feeds on a variety of fish, particularly the Arctic cod. Adult belugas are pure white, with bowheads being predominantly black with a characteristic white chin patch.*





*Bowhead whales are shown here swimming in the Beaufort Sea, which is their summertime feeding ground. (Photo courtesy LGL Limited).*

between late June and early August. The beluga is very social and travels in large groups - like most toothed whales, it has a very well developed capability for echo location and communication, and feeds on a varied diet of fish and invertebrates. In March and April of every year the beluga leaves its winter location in the Bering Sea, migrating through the Chukchi Sea, following leads in the pack-ice. By May they may reach leads in the area west of Banks Island, then turn south into the Beaufort and Amundsen Gulf usually reaching the mouth of the Mackenzie by late June or early July.

The area along the Tuktoyaktuk Peninsula to the Mackenzie Delta is an important travel and feeding route for the beluga, but by late August or early September they are already migrating westward out of that region. Their exact path west to their winter grounds is unknown, but it is speculated that their migration parallels the edge of land-fast ice, some considerable distance

off-shore. Reproductive rates for belugas appear to be low, with a female having one calf perhaps every three years. Scientists disagree on just how old belugas get, with estimates ranging between 25 and 50 years, dependent upon which aging technique is applied. Young belugas are grayish in colour but turn white by the age of three or four. The beluga's teeth are short stumps, not well suited for tearing flesh, but rather better for holding fish after they have been sucked in to the mouth while foraging on the ocean floor. The beluga is hunted by Inuit hunters all along the Beaufort coastline, and provides food and important by-products for native communities. For this reason the welfare of the beluga is of paramount interest to the residents of the Mackenzie Delta region.

The whale hunt and the products derived are important for their cultural, social, and nutritional benefits. Knowing this, for the past nine years, Esso, and more recently

along with Dome and Gulf have sponsored a whale monitoring program. In those nine years there has been no change in the population density of belugas, and the continued presence of thousands of white whales in the Mackenzie estuary suggests that there has been no serious or premanent effect on them from the hunt itself or industrial activities.

The bowhead, as mentioned previously, is a rare and endangered species of whale and the modest numbers are confined predominantly to Arctic waters. Virtually the entire population spends its summer in the Beaufort Sea, migrating from winter grounds in the Bering Sea during March and April, following ice leads parallel to the northwest coast of Alaska. Their exact route into the Beaufort varies dependent upon the leads, and different routes may be followed from season to season, according to ice break-up patterns, but bowheads can be seen in the Amundsen Gulf area by mid-June and in the

southeastern Beaufort by July. This general area is considered to be one of the main summer feeding grounds for the bowhead. Mating for bowheads seems to occur in the spring, prior to their arrival in the Beaufort, and even more so than the beluga, it is not a prolific species. A 1980 study spotted 11 calves in an estimated population of over 300 bowheads. At the present rate the bowhead appears unlikely to regain its former population density of the 19th century for a long time, if ever. Adults are mostly black in colour with white chin patches - although body colouring is quite variable, with white patches sometimes appearing on the whale's back, and gray patches, indicating recently sloughed skin, appearing in large areas on the body generally.

The bowhead migrates westward in September and October and seems to stay closer to the coastline, where there is open water along the north coast of Alaska, continuing to feed as it proceeds westward back to the Chukchi and Bering Sea. The exact travel movements and routes for bowheads are difficult to define, in part because the whale spends about three quarters of its time below the surface. Moreover, until recently there had been little systematic study of their feeding patterns and general behaviour. New studies sponsored by the U.S. Bureau of Land Management and the oil industry were initiated in 1980 to determine the possible impacts of industrial disturbances connected with offshore oil and gas exploration and development upon whale behaviour, especially the bowhead. Since whales such as the bowhead have well-developed hearing, they can detect man-made noises from boats, airplanes, and construction activities. But whether this noise backdrop affects the bowhead, or inhibits his migratory patterns, was unknown.

Aerial and surface observations conducted by scientists in 1980 and 1981 in the Beaufort Sea brought to light many interesting facts which suggest that the bowhead whale is little disturbed by boat traffic,



Photo courtesy LGL Limited

dredging, and island construction. In August 1980 a five day aerial count of bowheads around the Issungnak artificial island revealed that 162 whales were seen on the surface, with possibly many others swimming below. Some of the bowheads passed within half a mile of the island and even closer to barges working in the area. It appears that the bowheads can detect noise from the island at least three miles away, but do not change their feeding and swimming patterns because of it.

Experiments conducted using a 50 foot crew boat, the Imperial Adgo, and the larger Canmar Supplier IV, in August of 1980 revealed that whales generally didn't alter their pattern of movement until the boats came within about 2,500 feet.

Inside that distance they usually orientated themselves away from the boat, and within 1,000 feet, the whales generally dove, bringing their tail flukes clear of the water. However, once the boat passes beyond the 2,500 foot point, the bowheads continued their original activities, and remained in the area. They tend to spend less time on the surface when boats are passing through, and keep separated more widely.

Aircraft engine noise transmits easily through the water surface and evidence gathered in 1980 suggests that bowhead whales can hear aircraft traffic noise some distance away. Much of the tracking and counting of bowheads was conducted with a twin-engined aircraft. It was found that the whales paid little attention to aircraft flying at or above 1,500 feet from the ocean surface. Aircraft descending below 1,000 feet were both seen and heard by the whales, who would promptly dive below the surface.

Recent studies reveal that the ambient level of noise in the ocean is variable - it is not the silent region one imagines, and in the Arctic Sea the noise from ice impact and movement is considerable. While baleen whales do not have the well developed echo-location capability of toothed cetaceans, they do make noises which can be heard over a range of several miles. Since they do not rely on sound reflection to home in on objects, bowheads may be somewhat less noise sensitive than other species, although further research is necessary to determine this. At any rate their behaviour in the Beaufort Sea does not appear to have been altered by the presence of industrial activity, and there is no evidence that either the bowhead or the beluga are curtailing their migration routes, feeding patterns, or social activities because of boat traffic, underwater dredging, island building, and ice-breaking. The attention of the oil industry to these migratory and feeding patterns has allowed the industry to explore efficiently while minimizing potential disturbances to the whale population of the region.

*As viewed from the waterline, Hans Island is deeply indented with cuts in the rock face, and the significant height of ice floes hitting the island can be appreciated by comparing the man on the right with the rubble field at the base of the cliffs.*



## The Research Contribution of the Hans Island Project

*As our readers can see from this aerial view, Hans Island is a rugged piece of High Arctic terrain, with very little vegetation. The steep slopes form a buttress against the moving ice coming down the Kennedy Channel, with the peak of the island being about 200 metres above the water surface.*



In the words of one ice expert, "...ice is a very fickle material...". Studying it in the laboratory, under controlled conditions, although important, does not provide engineers with enough information about how ice will behave in large masses, such as encountered in the Beaufort Sea. Because ice is close to its melting point it displays characteristics not unlike steel when it approaches melting point - it becomes more flexible, compressible, and tends to creep. But at the same time ice is brittle - like toffee it can be stretched, but if hit with a hammer, it will shatter. To complicate matters further, first year sea ice, being about two metres (six feet) thick is not the threat to man-made structures that multi-year ice can be. Multi-year ice is the design baseline for constructing artificial islands because such ice is stronger and sometimes in excess of 6 metres (20 feet) thick. In the Beaufort Sea where artificial islands have been built, multi-year pack ice is not a constant winter event - perhaps once in three to five years the permanent polar ice will move south in significant amounts into the near coastal regions.

For engineering designers the question has been - how do we get real world data on multi-year ice that we know will be applicable to island building technology? To date, islands built in the Beaufort have had sloped beaches, whereas the latest design concept, reflected in the prototype Tarsiut just completed, has vertical concrete boxes, called caissons, rising from below the sea surface to a height of five metres (16½ feet). What was required was an island in nature with similar steep slopes, exposed to moving ice. There is such an island in the Arctic - it is called Hans Island, sitting at 81 degrees North latitude in the narrow Kennedy Channel separating Greenland from Ellesmere Island. It is actually the tip of an underwater mountain range and is virtually barren of vegetation and wildlife. One kilometre (0.6 miles) in diameter, this rock promontory stands in the middle of Kennedy Channel exposed to multi-year pack ice floes and even ice

islands broken off from the Ellesmere ice shelves.

In the summer of 1980 and 1981 oil industry research teams flew north out of Resolute Bay to Hazen Lake on Ellesmere Island, the jumping-off spot for Hans Island. Supplies for the several week sojourn on the island were flown to Ellesmere by a Twin Otter aircraft,

multi-year ice can drift at speeds exceeding one metre per second, dependent upon current and wind conditions, when crashing into the island. The scientists on the island learned that the ice decelerated and broke up in varied ways. Sometimes a large floe was preceded by an array of smaller floes which squeezed against the island and



*Ben Danielewicz, who headed up the seven-man scientific team that lived on the island in August of this year, is seen here installing a pressure gauge in the face of a large ice floe.*

and carried in sling loads by a helicopter, since the island is both too small and rough for conventional aircraft to land. Five scientists set up their tents for three weeks in the month of August, 1980, and using a variety of instruments, were able to obtain direct measurements of ice forces on a wide structure - something never previously accomplished. Their measuring techniques included the use of aerial and surface time-lapse photography, accelerometers, theodolites, a distance meter, a borehole jack, and airborne impulse radar.

During this period, collisions of ice floes up to several kilometres in diameter and eight metres (26 feet) in thickness were monitored. This

cushioned the floe impact. Some large floes were split upon impact with Hans Island, particularly if they were a mixture of first year ice and smaller, multi-year ice pieces, a not uncommon feature in Kennedy Channel.

Determination of the forces of impact required measurements of the ice floe's mass and its acceleration (based simply on Newton's Second Law:  $F=ma$ ). The scientists on Hans Island used a variety of methods to ensure the reliability of the data. Accelerometers were placed directly on the ice floe, one at the approximate centre and the other several hundred metres away, to measure the rate of linear and rotational



*Two researchers set in place one of the instruments on the ice foot of the island, and lower ropes over the side of the floe, which is several metres above the water surface, to lower down one of the members.*

deceleration of the floe. In addition theodolites placed on top of Hans Island were aimed at two easily identifiable points on the floe. From the azimuth and declination of these points over time, both deceleration and the motion of the centre of mass of the floe were calculated. Photography was employed extensively, with cameras on the ground providing time-lapse pictures 24 hours a day, and a helicopter photo platform hovering over the contact zone to record the ice failure mode and the floe rotation during impact.

To ensure precision measurements an infra-red, electro-optical range finder was utilized, accurate to 10 centimetres over several kilometres. To measure the thickness of the ice three methods were employed - surveys of freeboard with rod and level, direct measurements using an auger, and an impulse radar system mounted on the helicopter. A Fenco borehole jack system was used to measure the small scale strength of the ice and its elasticity. A portable meteorological station was set up to continuously monitor wind direction and velocity. The water salinity,



*A researcher climbs down the ice floe face in order to install a pressure gauge into the side of the ice, to provide data on the crushing forces of impact.*

current velocity and direction of movement in the Channel were also recorded.

Much of the data for the 1981 summer season on Hans Island are still being studied, and the program, initiated by Dome Petroleum Limited, but funded in cooperation with other oil companies, has already yielded invaluable data about ice interactions with large, steeply sloped structures. Since production islands will be about the same diameter and general shape as Hans Island, it has been an extraordinary natural laboratory for determining the forces of nature involved.

The results of the Hans Island research project are proprietary, but preliminary conclusions suggest that real ice forces are perhaps more modest than originally forecast. The industry is confident that the strength of future islands will make them more than capable of handling the ice forces. Hans Island, a small, natural fortress, has made a major contribution to our knowledge about building a man-made equivalent in the Beaufort.



Esso's Issungnak Island

## Concepts for Offshore Production Facilities

The oil industry first extended production to offshore regions back in the 1950s in the Gulf of Mexico. After many years of experience built upon the application of technical advances, there are large production platforms around the world accommodating drilling rigs, handling up to 60 or more wells, complete with living quarters, helicopter landing pads, and other support systems. Each geographic region imposes its own unique climatic conditions on the design of a production platform. In the Gulf of Mexico the design criterion is hurricanes - the platform must safely resist the forces of the 'one hundred year storm'. In the North Sea, severe storms must also be considered and platforms there can resist the 'one hundred year wave'. The shape, height, contour, and

strength of a production facility changes from one location to another, in order to meet the specific demands.

With the discovery of oil and gas offshore in Alaska during the 1960s, a new challenge was presented to the industry at Cook Inlet, because it is ice covered three to four months every year. Large ice floes, sometimes rafted up to four metres (12 feet) thick, and moving at speeds of six to eight knots had to be resisted by production platforms. The industry designed two new concepts to handle the environmental challenges faced. Today, a typical production facility in Cook Inlet is a four column platform, with a steel jacket, anchored to the seafloor by numerous steel pilings driven some 350 feet below the mud line. Unlike some warm water

platforms there is no cross-bracing between these legs, because that would present additional resistance to the ice. There is 50 to 60 feet clearance between the bottom of the deck and sea level at low tide to handle the very wide tidal range encountered in Cook Inlet.

A second kind of Cook Inlet design is called a "monopod", and to date is unique in the world. It has an hour-glass shape to cause the ice to climb the structure, and fail in bending, or move around the smooth cylindrical walls of the platform. This platform is both easy to transport and easy to submerge in position. It is anchored to the sea floor with pilings driven through horizontal pontoons which rest on the sea floor. Wells are drilled through the central protective column, which measures roughly

8½ metres (28 feet) in diameter.

Building upon the offshore history of the oil industry in Cook Inlet and the nine years of Canadian experience in the Beaufort Sea with artificial islands, we are able to project a well defined series of design concepts for future Beaufort Sea production. The industry has many options open to it and ongoing research is refining the engineering designs which will be necessary. At this time the industry cannot say categorically which option will ultimately prove most fruitful, only that there are opportunities to modify or combine the individual designs to create a safe and efficient

production system in the Beaufort.

In general terms the industry envisages both production islands and oil tanker loading facilities in the Beaufort. Whether the production islands incorporate harbour or docking facilities, or whether the harbours are separated from production, but connected via a pipeline gathering network has not been finalized. Platforms will be exposed to different forces depending on their location in either shallow water under 25 metres (80 feet), which is the edge of the landfast ice, or in deep waters such as those in the area of the Kopanoar oil field. In deep waters a greater frequency of

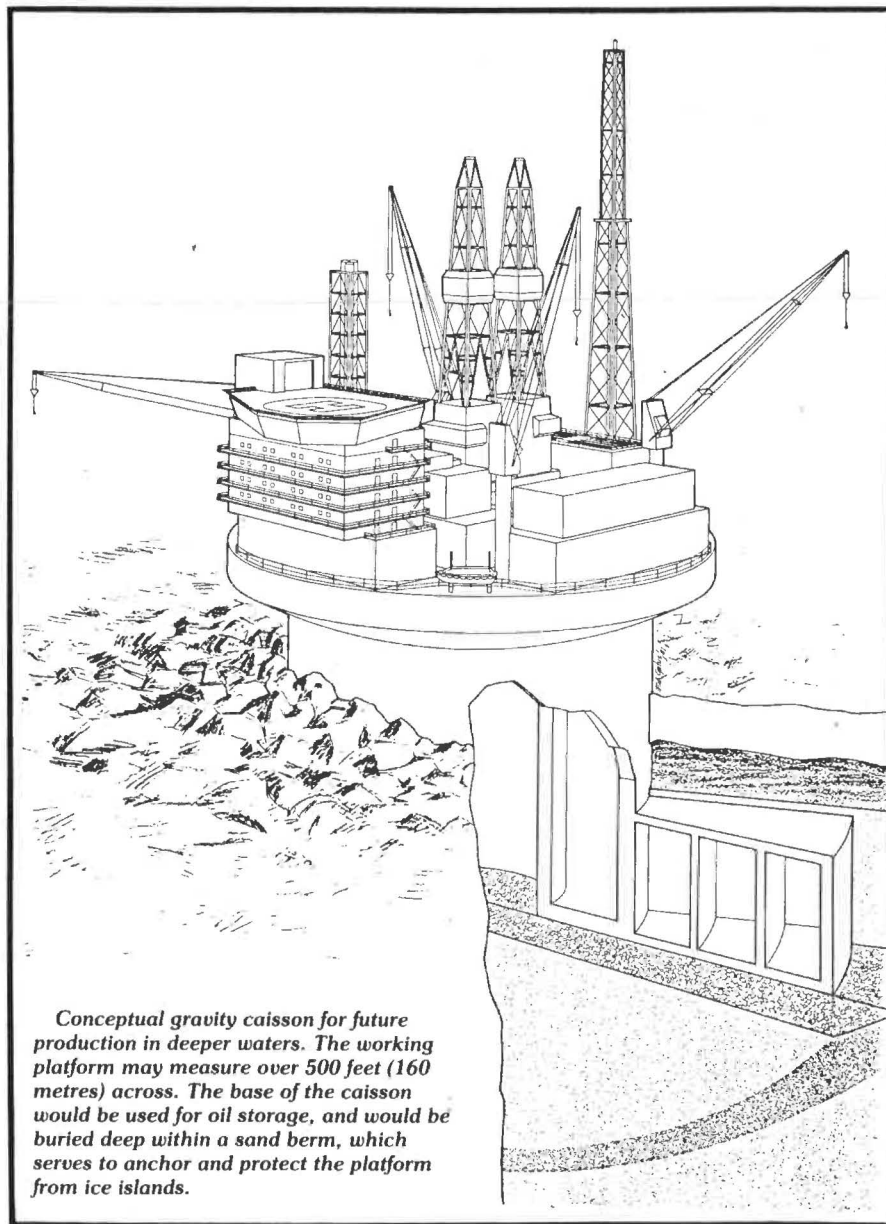
multi-year pack ice must be handled and ice islands must be considered in the design. The probability of an ice island hitting a production facility is remote, but like the 'hundred year wave' of the North Sea it must be considered during evaluation of engineering concepts.

## Production Islands

In shallow waters, the well proven concept of sacrificial beach islands such as Issungnak would provide a safe foundation over a long period for permanent drilling and producing facilities. They can be enlarged, as necessary, and slope protection to minimize damage by ice or wave erosion is well developed. They are a good structure within the landfast ice zone, but the caisson island may be preferable as the industry moves further out. For a detailed description of one model of caisson island, our readers are directed to our story on the building of Tarsiut in this issue of **Beaufort**.

Tarsiut can be expanded into a production island, by installing more and larger concrete caissons around the perimeter of the existing island and filling in with sand - a production island needs to be higher, stronger, and have more working area. This 'growth' could take place while drilling operations continued unimpaired, and the industry has several options in expanding the basic structure. The production facilities can be brought in by barge or other unitized means to dovetail into a prepared sub-surface. A protective berm would then be placed around the facilities.

There are other applications of the concrete caisson technology besides Tarsiut. One is called a caisson gravity structure - not as elegant as the monocone style used at Cook Inlet, it relies on brute strength and sheer weight to resist ice forces. It can be made with vertical or sloped walls, is totally prefabricated in a southern port, and has the majority of its drilling and production facilities in place prior to being towed to the Beaufort. One of the advantages of a gravity caisson is that substantial oil storage is possible within the



*Conceptual gravity caisson for future production in deeper waters. The working platform may measure over 500 feet (160 metres) across. The base of the caisson would be used for oil storage, and would be buried deep within a sand berm, which serves to anchor and protect the platform from ice islands.*

structure. Another advantage is that, dependent upon structural refinements, a minimum of ice rubble fields will grow around it, thereby allowing tanker access to the caisson on the "down-stream" side of ice movement. The exact shape of a gravity caisson could vary; it might be simply a pillar with straight sides, or it could have a flanged top and bottom to provide a larger working surface and base. The base of such a large production caisson might measure 250 metres (over 800 feet) across, the neck of the caisson being 120 metres (400 feet), and the working platform 160 metres (over 500 feet).

Such a deep water production island would likely have integrated facilities that would be pre-commissioned prior to arrival in the Beaufort Sea. The platform would thus be built up in a practical and efficient manner, in the South, utilizing existing, well established construction techniques.

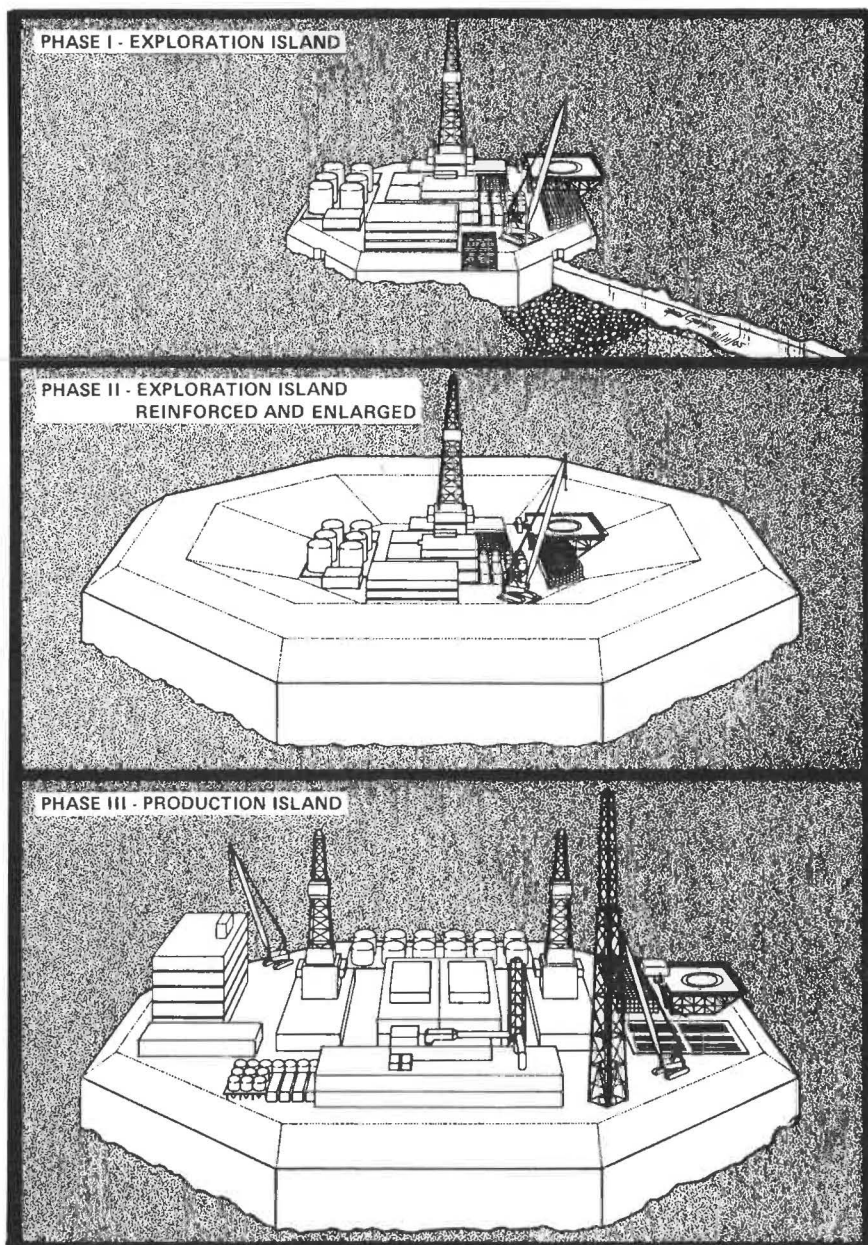
The industry is considering several options to transfer and collect the oil in the Beaufort. The oil might be run by pipeline to shallower water to an Arctic Production and Loading Atoll (APLA) or some harbour variation thereof, or perhaps to another island with a single point mooring facility. Each of these options have advantages, but also technical problems to overcome, and the ultimate design will reflect the best combination of safety, efficiency and cost effectiveness.

Another application of island building is the APLA, Arctic Production and Loading Atoll, which would allow tankers to berth and load up with oil. An APLA is actually two large banana shaped islands, forming a protective shelter, with entry and exit ports. The key components for the APLA system would be facilities to store produced oil and to transfer the oil into tankers. If the APLA were located over a field the facility could also accommodate drilling and production at the same time. The exact configuration of an APLA is still being refined, and its final ap-

pearance might differ from conceptual drawings, but the principles would remain constant. It is likely to be about a kilometre (0.6 miles) long and use caissons or some other form of protection around the perimeter of the berms. The harbour itself would be large enough to allow tankers to maneuver safely year round. Some form of ice management scheme, such as icebreakers to break up and push away ice would have to be employed mainly inside the APLA to keep the harbour interior from jamming up with excessive ice. An

alternative design might be a production island and one banana shaped island, combining the qualities of islands and APLAs into one.

The components which will eventually constitute the Beaufort Sea production system will reflect the steady and sensible application of known technologies, from offshore areas world-wide, as well as the experiences gained in the Arctic. What is taking place today is the research foundation to optimize the knowns into an efficient, environmentally safe, and cost effective network.



Conceptual conversion sequence from an exploration to a production island.

*With the four concrete caissons in position, Tarsiut takes form in the Beaufort Sea. After being filled with sand and topped off with a gravel surface, drilling equipment was put in place using the giant cranes shown around the circumference. Each caisson weighs 5,300 tons and measures 80 metres (262 feet) long. They were built at a cost of \$27 million dollars in Vancouver, B.C. and towed by barge to the Beaufort in July of this year. When empty the caissons float; they are sunk in position by flooding with water, then filled right to the top with sand to form the perimeter reinforcement for the island.*

